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SHORT ARTICLE

Controlling Town Industry Explosion Hazard in China

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Abstract This article introduces industrial safety issues encountered in the towns of China, points out the importance of damage control of industrial explosions and disaster management, and puts forward suggestions on safety design and management intended to reduce the frequency and impact of industrial explosions in Chinese town areas.

Keywords Damage control · Industrial explosion · Safety design · Town industry

1 Introduction

Urbanization and industrialization in China have advanced greatly since the country's economic reform and opening-up in the early 1980s. The urbanization rate reached 56.1% in 2015 (National Bureau of Statistics 2016) and the industrialization rate was 46.8% in 2011. In 2013, there were more than 12 million small and medium-sized enterprises (SMEs) across the country (Huang et al. 2014). Booming town industries have created a great number of safety issues.

In this short article, town industry refers to industrial facilities located in town areas that have business and industry and where the population is predominantly engaged in nonagricultural work. Industrial development in Chinese towns has experienced three developmental stages in the past nearly four decades: (1) in the beginning of the reform and opening-up, China made great efforts to develop township enterprises in order to improve its rural economy; (2) beginning in the early 1990s, national policies strongly encouraged the development of small and medium-sized enterprises, joint ventures, and industrial parks; and (3) at present, the government has started to adjust the industrial structure to promote the coordinated development of primary, secondary, and tertiary industries, to encourage the development of new high-technology industries, and to facilitate the integration of science and technology into industrial development (Liang and Liang 2011).

During the second stage of industrialization, particularly in the early 1990s, industrial operations in China were prone to accidents of various types. Currently nearly half of China's provinces and regions are still at this stage of development (Huang et al. 2014). Town industries that remain in this development stage face greater safety challenges than do their more successful neighbors (Chen et al. 2012; National Bureau of Statistics 2013; Huang et al. 2014).

The stagnation of industrial safety is related to many factors, but is especially due to:

(1) An ever-changing production technology, large facilities, and flammable and explosive raw materials and products, which are the three most common characteristics of these industries. During the process of urbanization, these properties of industry cause greatly increased safety risks and more frequent industrial disasters and accidents;
(2) The absence of a clear separation of production activities and residential areas in many town areas. As urban expansion takes place, industrial production

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areas are increasingly in close spatial proximity to residential areas. When an explosion occurs in an industrial facility, especially one that is chemical related, the impact can have very disastrous consequences. The Qingdao pipeline explosion on 22 November 2013 exemplifies the problem (State Administration of Work Safety 2014). As the city's residential areas grew, they crisscrossed the petrochemical plants and pipelines that are located in the suburbs of this coastal city. The explosion killed 62 and injured an additional136 people, including pedestrians, staff on duty, local residents, and workers in the factory's temporary living quarters, which were located near the explosion site;

(3) A low level of technology and equipment and weak safety awareness, which is characteristic of many SMEs. For example, in most enterprises of Suzhou City in Jiangsu Province, problems of safety management confusion, poor education and training, and lack of motivation to screen out and eliminate hidden risks are still widespread (News of Jiangsu Provincial Committee of the Communist Party of China 2015);

(4) The lack of supervision and inspection capacity, which poses critical challenges to production safety law enforcement at the local level. For the over 12 million SMEs nationwide in 2013, the number of safety inspection personnel was less than 80 thousand;

(5) The large number of new migrant workers working in high-risk industries, whose lack of training and experience also increases the risk of industrial accidents. In the process of urbanization, many people migrate from rural to urban areas. According to the statistics, in 2012, China has 262.61 million migrant workers, more than half of whom are engaged in high-risk industries and less than 30% received vocational training. Among the victims in production safety accidents, more than 80% are migrant workers.

2 Importance of Controlling Town Industry Explosion Hazards

Town industry explosions will incur serious economic losses and casualties, and will cause concern and fear on the part of local residents. The Kunshan factory dust explosion on 2 August 2014 is an example: the explosion killed 97 people and injured 163 more, and caused a direct economic loss of RMB 351 million Yuan (Han 2015). Controlling town industry explosion hazards has the following benefits:

(1) Lower vulnerability of and impact on local residents. In Chinese towns, population and wealth are highly concentrated. Due to the often-limited financial resources of individuals, weak local disaster response capacity, and poor infrastructure, the vulnerability of town residents due to an industrial explosion is often high. Through reducing the risk of industry explosions, disaster impacts can be reduced;

(2) Reduce the uncertainty of explosions. The causes, location, frequency, trend, and scale of industry explosion are uncertain and are affected by many factors, which include human behavior and environment. By investing in hazard control, knowledge of potential safety risks can be improved and the uncertainties about accident occurrence can be minimized;

(3) Facilitate sustainable growth of towns. A reduction in the frequency and impact of industrial explosions would have a very positive effect on the sustainable growth of a town; and

(4) Improve the capability of governments and the public to deal with unexpected incidents. The hazard-coping capacity of both public and private sectors urgently needs improvement through technical, educational, and legal means to prevent and control disasters.

Blast accidents are usually abrupt, happen in a short time, and have serious consequences. The hazard literature suggests that focusing on prevention should be the basic principle of explosion hazards control (Chen 2011). The aim is to stop potential accidents from happening, contain the impact of accidents that have happened, limit the damage of blasts by restricting the spatial expansion of blast impacts, and prevent similar incidents from occurring in the future. Industrial explosion research in China has mainly focused on explosion theory and examined various contributing factors, such as natural environment, industrial production and management, and human behavior factors. Laboratory tests, computer simulations, and systems engineering approaches have been used to study explosion hazard, assess hazard risks, develop control technology to limit damage effects, and enhance post-disaster treatment. Although great achievements have been made in town industry explosion control, there are many questions in need of further research, such as how to build an efficient and orderly control system that minimizes or eliminates the town industry explosion hazard.

3 Town Industry Explosion Hazard Control

Safety design, such as warning systems and effective control or elimination of sources of danger, can prevent accidents. Safety management can prevent dangerous factors from forming.

3.1 Safety Design Against Town Industry Explosion Hazard

The town industrial explosion hazard is influenced by a variety of factors—the basic characteristics of town industries; the state of their explosive material control; the degree of explosive source elimination and remediation; and the implementation of safety systems that dampen explosion impact—processes that encourage a precautionary approach to hazard management that seeks gradual improvement of a difficult situation. This hazardous condition developed incrementally, but is hard to reverse quickly. Zhou and Chen (2002) advocate three safety design principles that should govern future new industrial development: (1) firms should avoid sites where explosions can be caused by natural disasters; (2) the interplay between hazardous sources and surrounding environment must inform future planning. Town residential layout and industrial business expansion need to take place based on land use zoning that separates housing and commercial land uses from potentially hazardous industrial activities; and (3) the overall layout of a hazardous industrial source and production complex must achieve control over the potential hazard impact of each enterprise's normal production and minimize any impact should an accidental and unforeseen explosion occur.

Safety design should include safety techniques that can prevent accidents and reduce losses. Safety techniques are intended to control and limit highly dangerous hazards and explosive sources in order to prevent accidental explosions. Three commonly used safety designs involve: (1) the monitoring of materials and energy that can lead to an explosion, such as a multichannel monitoring system for near real-time VOC (volatile organic compound) measurement in a hazardous waste management facility as suggested by Je et al. (2007); (2) strict confinement of explosive materials and sources. Limit explosion load to reduce risks, such as strengthened ventilation systems, which can decrease chemical concentrations and reduce explosive energy; and (3) separating explosive materials from explosive sources and potential oxidizers, which can be achieved by storing and handling explosive components in an inert state or employing explosion-suppressing processes (Amyotte 2006).

Safety techniques must be implemented that prevent equipment failures by regular inspection and proactive replacement, strive to reduce and (if possible) eliminate human mistakes, counteract adverse environmental factors, and upgrade poor management. The goal is to introduce generic procedures that eliminate all factors in a specific situation that can lead to explosions. One such practice is to separate facilities and environments that could lead to explosions from public spaces and densely crowded residential areas. This goal could be achieved by building shock-absorbent partition walls to prevent explosion impacts from spreading to adjacent areas. Creating a network of detectors and alarms in dangerous explosion source areas is another potential hazard-dampening mechanism. When an alarm is set off, immediate action can be taken to shut down and evacuate the threatened site. After an accident has taken place, timely evacuation of workers and local residents from the danger zone must be implemented (Wu and Gao 2001; Wang and Chen 2014).

Town industrial explosion hazards mainly involve chemical leak accidents, which are often caused by either technical failures or human mistakes (Jin 2000). Therefore, the following sections discuss how to handle and prevent explosion hazards from the perspective of management.

3.2 Improve Education to Raise Awareness and Establish a Comprehensive Management Plan

In order to prevent explosions, governments at all levels must carry out training and drills regularly among all communities. These exercises raise the public's safety awareness, and help technical staff and new employees of industrial companies to improve safety skills. Government officials must also learn how to respond to explosion disasters effectively through these efforts. Authorities can take advantage of mass media to raise public awareness of relevant regulations and emergency plans for enterprises and residential buildings. They can also set up warning and alarm systems if necessary. Governments at all levels should construct a set of coordinated crisis management mechanisms, and include disaster emergency management in their development plans (Jones et al. 2015). Only in this way can society detect and prevent potential industrial explosion disasters in advance, and deal with explosion accidents effectively and orderly when, unfortunately, they do occur.

3.3 Develop a Village-Town-County Three-Level Explosion Prevention Mechanism and a Risk Control Strategy

Work safety authorities should set up a multilevel industrial explosion prevention system based on their mandate and monitoring procedures. Governments at all levels need to examine, monitor, and advise on the safety work of subordinate government levels, and make transparent their budgets and plans for work safety. Work safety authorities can regularly invite experts to conduct safety training programs, organize seminars, and provide advice on how to prevent industrial explosions.

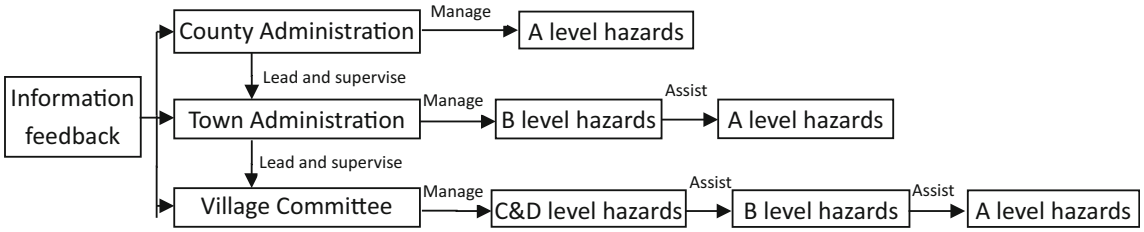

Fig. 1 Village-town-county three-level explosion prevention mechanism. *Source* Chen and Chen (1996)

Generally, work safety authorities divide their duties as follows. County authorities are mainly responsible for Class A hazards (Fig. 1), which are very dangerous, hard to control, and prone to cause large casualties. The main duties of township authorities lie in the control of Class B hazards, which are dangerous, hard to control, and likely to cause casualties. As part of their mandate, township officials also assist in controlling Class A hazards. Safety workers at the village level mainly deal with Class C hazards, which are not likely to cause explosions but often result in accidents, and Class D hazards, which can be dangerous and lead to small accidents. Village safety workers also need to help prevent Class A and B hazards (Fig. 1).

Work safety authorities also must define potential explosion hazards in town areas, so that personnel in charge, safety workers, and residents can have a clear picture of the explosion risks around them. With this information, they can assess the severity of these risks based on qualitative and quantitative evaluations, and decide on risk control measures and priorities. Specific explosion prevention and control measures can be made based on the evaluation and practical needs.

3.4 Refine and Renew Explosion Hazard Control Regulations and Strictly Enforce Work Safety Standards

It is of fundamental importance to refine and update relevant explosion prevention regulations, and strictly enforce work safety standards, in order to reduce industrial accidents and causalities. At present, China has about 300 state regulations and around 600 industrial standards concerning explosion hazards.[1] But many of these regulations and standards are outdated and lack proper technical and systemic guidance; some of them cannot be applied in practice to solving real problems. Moreover, some standards are not consistent with international standards, which undermines their effects and functions in guiding industrial practices. Many regulatory departments have overlapping mandates. Therefore, regulatory authorities are advised to review the existing explosion control regulations and standards, identify those in need of revision, and then enact and revise regulations and standards in accordance with practical needs. Authorities also should raise China's industrial standards to an international level and implement them in various operational and management activities.

3.5 Set Up Effective and Systemic Industrial Explosion Hazards Control Mechanism

The industrial explosion hazards control mechanism consists of disaster monitoring and forecasting, disaster relief, and post-disaster recovery components. It is recommended that each administrative area sets up a special organization to deal with the industrial explosion hazards within its borders and to improve cooperation with other regions. A contingency capability appraisal system should be created based on each area's industrial explosion threats, the perceived vulnerability of its public service systems (for example, water supply system) and existing or proposed emergency management skills. Cooperation and joint action should be strengthened among various government organizations, between governments and nongovernmental organizations, at the interface between government and the media, as well as between governments and research institutions. An effective disaster control system will enable better allocation of disaster relief resources and make sharing information both possible and more frequently attained.

3.6 Invest More Resources to Effectively Control Industrial Explosion Hazards

Explosion prevention is dependent on an ability to detect and identify potential threats. Only then is it possible to document, register, and evaluate the threats comprehensively. An effective preventive protocol involves making contingency plans for possible explosions. Each step of the above process requires consistent government spending and input, which may include policy incentives, financial support, and human resources. Governments may install

[1] http://www.csres.com/sort/index.jsp; http://code.fabao365.com/.

fiscal incentive policies that promote work safety and explosion prevention. These policies might include tax cuts for technology firms that specialize in explosion hazards control. Governments need to increase fiscal spending on work safety and explosion prevention and put such spending into their budgets. Moreover, government entities at all levels should also manage work safety funds to raise their efficiency of use. It is necessary for governments not only to employ safety experts to provide training and consultation, but also to attract outstanding personnel to join the public administration sector. Governments can also set up special education programs to train personnel for industrial explosion hazards control.

4 Conclusion

In examining safety problems confronting town industrial development and analyzing the importance of industrial explosion hazards control, this article proposes work safety planning improvement and work safety management as key measures. Because governments of higher levels and line authorities in charge have more resources in terms of management, skills, and coordination, they are more capable of effectively preventing and handling major explosive hazards. Multilevel management of industrial explosion hazards makes objectives and duties clear and authorities more accountable. Some sectors and companies have applied this management method in their operation, which has produced favorable results in return.

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